DRAFT STATEMENT OF WORK (SOW)*[1],[2]

Title: "Ice Water Content Tomography System and Software Development"

BACKGROUND

Computed Tomography (CT) is most widely known for its use in medical imaging where scans using X-ray wavelengths are taken around an axis of rotation and mathematical processing or reconstruction is used to produce a three-dimensional image of the inside of the body. In this technical effort the illumination sources are in the visible wavelength regime and detectors around the axis of rotation will measure the absorption characteristics as the light passes through a cloud of liquid droplets and/or ice particles. Tomographic reconstruction will be used to produce a two-dimensional image of the cloud uniformity ([ice] water content) within a single plane of the cloud as it travels down a round duct.

SCOPE OF WORK

The goal of this technical effort is to provide hardware design support to NASA engineers through modeling efforts in support of the development of a non-intrusive ice cloud characterization tool for use in engine icing research and to provide the data acquisition and analysis software to be integrated with NASA hardware. The system shall provide nearly real-time water content uniformity in a plane of a 36-inch duct coupled to an engine inlet. The targeted ground-test facility for integration of this diagnostic tool is the Propulsion Systems Laboratory (PSL) at NASA Glenn Research Center (GRC).

The PSL facility is undergoing modifications to add ice crystal generation capabilities upstream of the engine inlet to enable ground-based engine icing research at altitude conditions. The facility needs a non-intrusive method for determining the ice cloud characteristics prior to engine ingestion. The goal of this technical effort is to provide ice cloud content uniformity using an optical tomography approach. The particle size distributions and ice crystal number densities shall be measured by NASA independently from the optical tomography system via other measurement devices and shall be provided to the Contractor as they become available; they will not be measured in-situ. The ice clouds will ideally have similar characteristics and conditions to the meteorological conditions that are expected during in-flight icing, potentially leading to flight

[1] A majority of this SOW is complete, and NASA feels that this current version represents a significant portion of the work under this planned procurement. Changes in detail may be forthcoming to this SOW though, and may be in the form of insertions or deletions of specific sections of this SOW. Any changes to the SOW will likely not be made to this Sources Sought Synopsis. These changes would likely be evident in any Solicitation that may result from this Sources Sought Synopsis.

[2] In addition, it should be noted: NASA is NOT asking for any proposal to this effort at this current time. Please only provide the information stated on the cover statement page of the Sources Sought Synopsis. This Statement of work is being posted for market research purposes only. It is NASA GRC's intention, however, to solicit bids after the closing date of this Sources Sought Synopsis depending on the results of this posting.

hazards. The predicted ice particle size range is 10 – 200 micrometers with ice water content (IWC) in the range of 0.5 – 9 g/m^3; actual values shall be verified experimentally by NASA and provided to the Contractor at a later time. All instrumentation must be mounted external to the 36-inch duct; a 12-inch wide section of the duct wall is available for hardware placement.

The suggested approach is to use an optical absorption system with multiple sources and detectors in a circular array around the plane of interest to provide ice water content information. Using computed tomography analysis methods, the intensity information from multiple detectors shall provide a planar map of the normalized ice water content to verify uniformity across the tunnel cross-section. The spatial resolution in the resulting ice water content map shall be better than 1-inch within the central 75% of the 36-inch diameter duct; lesser resolution (between 1-2 inches) is acceptable in the outer 25% of the duct cross-section. The Contractor shall develop simulation software for hardware design optimization as well as data acquisition and cloud image reconstruction software that accepts sensor and control data from facility hardware and provides on-screen ice cloud density images almost immediately following data acquisition with update rates at a minimum of once per spray acquisition (approximately once per 1-2 minutes). The software shall also allow for storage of raw data and reconstructed images.

Upon completion of this contract, the Contractor shall provide a software package that integrates with an optical absorption ice cloud tomography system and provides nearly real-time feedback on the uniformity of ice clouds generated in the PSL facility. NASA will build the hardware based on design recommendations from the Contractor. The data acquisition and image reconstruction software shall be delivered to NASA with installation and integration support from the Contractor.

The Contractor must provide evidence in the proposal of previous experience developing custom computed tomography algorithms for custom geometries and multiple-scattering situations. The Contractor must also provide evidence of previous experience developing computed tomography software for commercial-use systems outside of a research environment. As part of the proposal the Contractor shall provide details of custom algorithm(s) that will be adapted to satisfy the requirements of this Contract. The Final Contract Deliverables shall be delivered to NASA no later than TWO years from the initial Contract start date.

Detailed task elements are defined below.

TASKS

Task 1. Administrative Requirements

The Contractor shall deliver all reports/data in accordance with the requirements of the Reports of Work Clause. Specifically, the Contractor shall provide a Work Plan, technical task reports, the Final Report, and any other applicable reports.

All deliverable Sketches, Drawings, Designs, etc. shall conform to the requirements set forth in the Drawings Clause.

Upon approval of the initial Work Plan by the NASA COTR, the Contractor shall commence Task 2.

Task 2. Develop 2-D Ice Droplet Cloud Density Simulator and Data Acquisition Simulator

The Contractor shall

2.1 Develop a numerical model to generate optical absorption data representative of a 2-D ice droplet cloud based on particle size and number density requirements as provided by the NASA Contracting Officer's Technical Representative (COTR). The number of simulated clouds will be defined by the NASA COTR, but will include, at a minimum, three cases: low, medium, and high number density cases, each with a nominal particle size distribution.

2.2 Generate representative cloud absorption data based on THREE hardware configurations as provided by the NASA COTR. Each hardware configuration will be defined by locations and types of sources and detectors around a fixed-diameter duct.

2.3 Build a data acquisition simulator that accepts typical experiment data based on the source and detector characteristics as set forth by the NASA COTR and which can be modified to model the THREE NASA hardware configurations as defined in sub-task 2.2.

2.4 Deliver Task Report for Task 2.

Task 3. Tomographic Reconstruction Development and Hardware Design Optimization

Upon approval of the Task 2 Report by the NASA COTR, the Contractor shall

3.1 Develop and implement tomographic reconstruction algorithms for the THREE NASA hardware configurations and the modeled ice cloud characteristics.

3.2 Generate reconstructed cloud density images for each of the THREE NASA hardware configurations using each of the simulated cloud data signals from task 2. If available, also perform reconstructions for NASA-provided laboratory data. Evaluate the spatial resolution and accuracy of the reconstructed cloud content for all configurations.

3.3 If any of the simulated configurations meet NASA's requirements for resolution and accuracy, then recommend the best hardware configuration for NASA to proceed in building for the Propulsion Systems Laboratory at Glenn Research Center.

3.4 If none of the configurations provide an acceptable system based on defined requirements then NASA and the Contractor shall work together to establish new hardware configurations to evaluate using the simulator tools.

3.5 Report findings and recommendations to NASA COTR.

3.6 Upon NASA COTR's approval of the recommendations, iterate on sub-tasks 3.1 through 3.5 for any new hardware configurations or move on to sub-task 3.7.

3.7 Refine and finalize hardware design recommendations and reconstruction algorithm.

3.8 Deliver Task Report for Task 3 and present hardware design recommendations to NASA.

Task 4. Tomographic Data Acquisition and Reconstruction Software Development

Upon approval of the Task 3 Report and the hardware design recommendations by the NASA COTR, the Contractor shall

4.1 Develop a prototype software package that accepts sensor and control data from the PSL facility data acquisition system and generates and displays ice cloud images. The reconstructed cloud images shall be displayed no later than 2 minutes after the data acquisition time period has commenced. The software shall store raw data and reconstructed images. The software shall have the capability of loading previously acquired and reconstructed cloud image data, as well as the ability to reconstruct previously acquired raw cloud absorption data. The software shall also offer the capability to visualize ice cloud variation over time, and also to provide a running average of the spray that is updated after each new acquisition throughout the spray duration (not to exceed 30 minutes).

4.2 Generate a design document that includes data flow, GUI components, descriptions of data formats and communication protocols.

4.3 Implement the software within the NASA hardware framework using Interactive Data Language (IDL), or other defined programming language as approved by the NASA COTR. NASA shall provide to the Contractor any necessary prototype hardware for completion of this sub-task.

4.4 Demonstrate a working prototype of the integrated system using simulated and/or laboratory data inputs and simulated control and communication.

4.5 Deliver Task Report for Task 4 and the software operator's manual.

Task 5. Install, Integrate, and Demonstrate Software with NASA-Provided Hardware at PSL Facility

Upon approval of the Task 4 Report and the software operator's manual by the NASA COTR, the Contractor shall

5.1 Install and integrate the software at NASA with PSL facility hardware and data acquisition components.

5.2 Demonstrate live system operability.

5.3 Provide training to NASA personnel.

5.4 Provide troubleshooting services as needed.

5.5 Deliver operator's installation and maintenance manual.

5.6 Deliver software source code. Proprietary components may be blocked from access.

5.7 Deliver Task report for Task 5 and the Final Report for Contract Completion.